Great Lakes-St. Lawrence Basin Project: What Have We Learned?

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Their presentation provided an overview of preliminary findings of the GLSLB Project. The Project, launched in 1992, is a joint Canada-US research initiative lead by Environment Canada's Environmental Adaptation Research Group and the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Laboratory. It aims to better understand the complex interactions between climate and society, so that informed regional adaptation strategies can be developed in response to potential climate change and variability.

When we were preparing for this talk on what we have learned in the Great Lakes-St. Lawrence Basin (GLSLB) Project, we realized that it was in May 1992 that the first Steering Committee meeting for GLSLB Project was held. Five years later, we are presenting what have we learned. The primary lesson is that the people involved in the Project have made the difference. Although we are the Project Co-Chairs, we are indebted to the Steering Committee members who have contributed their ideas, helped steer and encourage us, as well as to the researchers who have spent a great deal of time, thought, and effort in contributing to the science.

The presentation today will focus on some of the key components of the GLSLB Project, including:

- project design,
- research framework,
- scenario development,
- climate change and variability impacts,
- adaptation,
- integration, and
- communication.

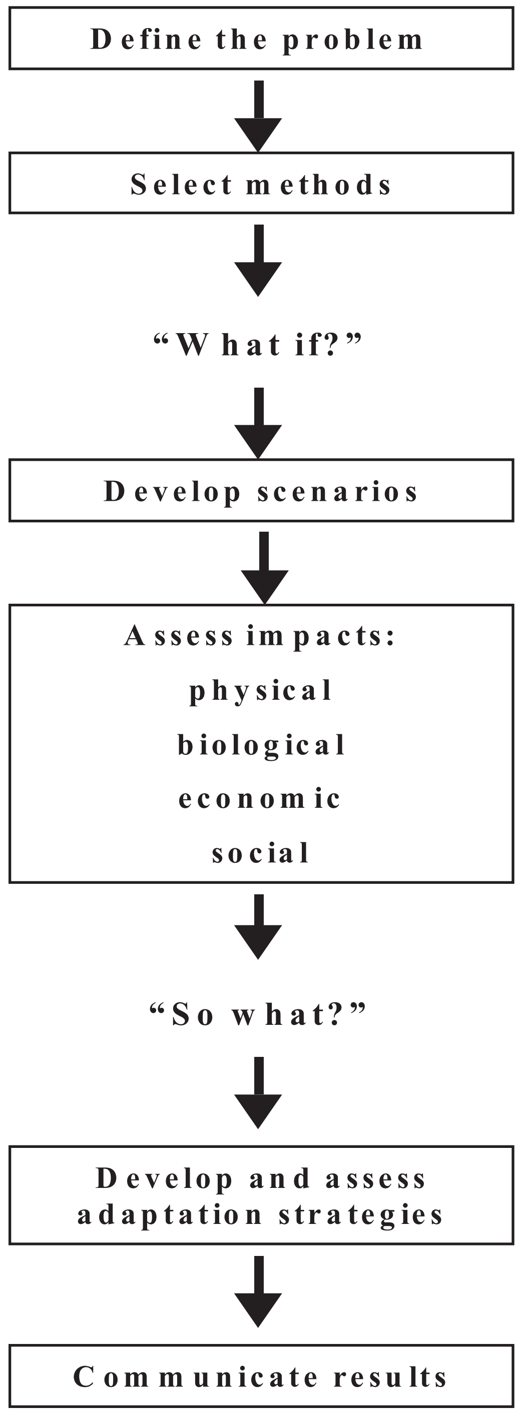
Project Design

What are some of the considerations when designing a climate impact study, whether it is one with small-scale, single-sector focus or a large-scale study of a region? The process of a climate impact assessment is outlined in Figure 2.12. Two phrases are extremely important to define the problem, select methods and undertake the assessment. First, the question, “If this were to occur, what would be the impacts?” (or “What if?”), is extremely relevant to developing scenarios and assessing impacts. Second, the question, “So what?” reminds us that simply identifying a problem is not sufficient. Solutions must also be developed; this is the adaptation component. Communication of climate change information to various publics increases their appreciation of the “What ifs?” and “So what?,” and contributes to their understanding of climate change science, impacts, and adaptation strategies.

The GLSLB Project had a number of goals. The impacts of climate variability and change were assessed under four general themes: water use and management, land use and management, ecosystem health and human health.

Key principles guided the selection of component studies and the implementation of the Project. Research projects were required to emphasize the socioeconomic impacts of climate change, identify strategies for adapting to climate impacts, demonstrate integration, and build on existing research. Under the Project, researchers were encouraged to not simply identify problems, but also to demonstrate how people, sectors, and regions could develop adaptation strategies to reduce their vulnerability to climate and to be pro-active with respect to these “What if?” scenarios. Also, collaborative partnerships with researchers in other disciplines and with other agencies were formed since outreach was necessary to share

Figure 2.12
Six Steps in a Climate Impact Assessment
(modified from Carter et al. 1994)



knowledge and build capacity for understanding the climate change issue and to develop adaptations. Communication was promoted to key affected groups or people, both at the broader Project level and within the individual studies.

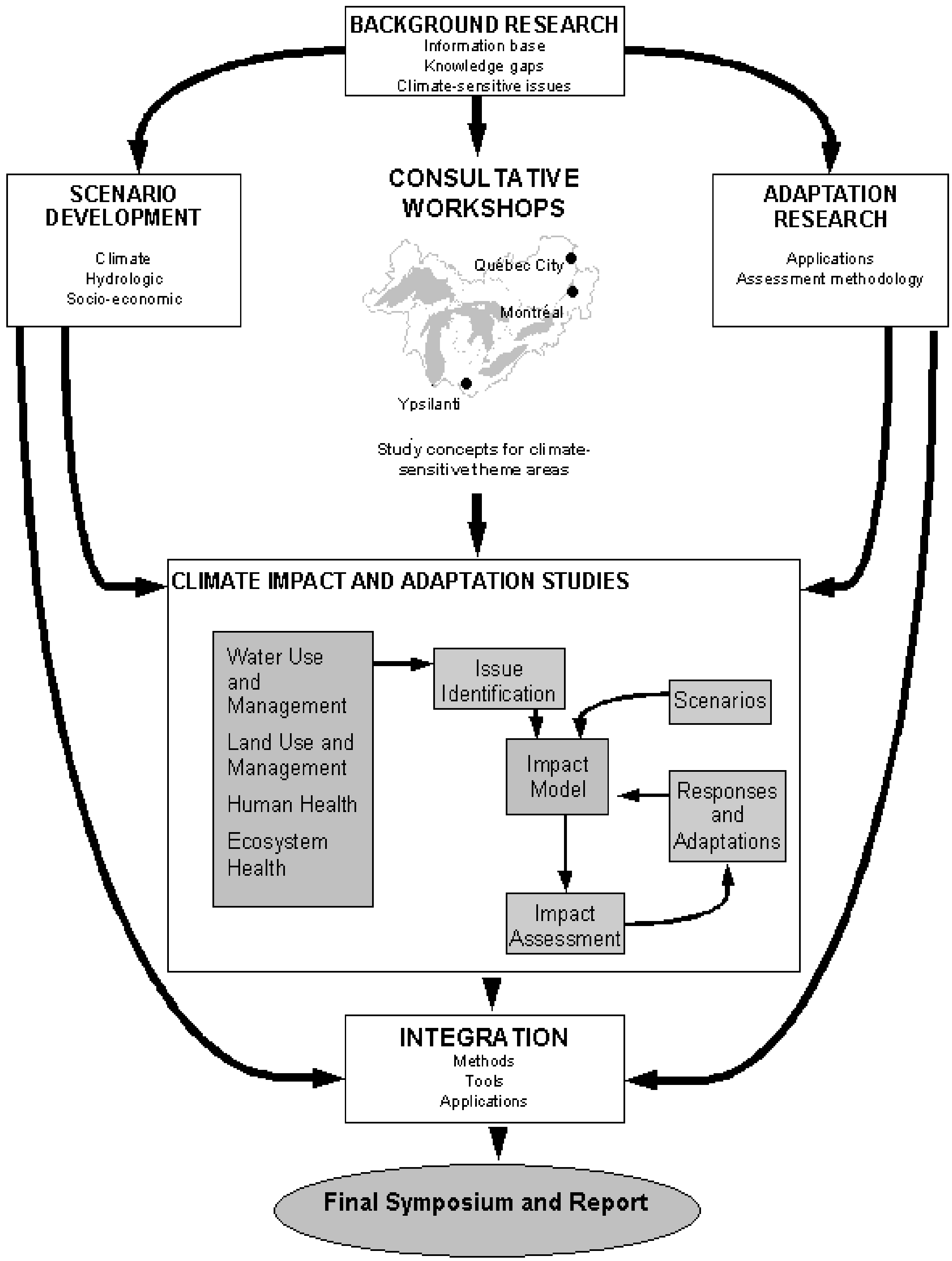
What have we learned in defining the problem? There are a number of questions that require consideration: "For whom is the project or study being undertaken?" "What are the anticipated outcomes?" Science goals are the substantive and methodological contributions; however, the Project's contribution to policy formulation and decision-making is the other important component of climate impact assessment. The climate change issue is so multifaceted, so far-reaching and complex that no single discipline can answer all the questions and provide all the needed expertise. Many people from many different disciplines must work together. Developing multidisciplinary partnerships poses a challenge, constantly requiring an immense amount of effort. Collaboration requires that researchers become fluent in, understand and appreciate other disciplines, as well as instruct others about their own discipline. Defining the problem requires defining the study area. One might pose questions such as: "Is the study area I have chosen representative?" "Is the information from this area transferable to other regions?" "Is the scale relevant to the research and stakeholders?" The large size of the GLSLB Project study area was not a comfortable scale for many of the researchers. Climate and hydrologic scenarios were developed for the entire Basin, but most of the component research studies focused on much smaller portions of the GLSLB, where data, models and expertise were available.

"The climate change issue is so multifaceted, so far-reaching and complex that no single discipline can answer all the questions and provide all the needed expertise."

Research Framework

Figure 2.13 outlines the research framework for the GLSLB Project. The first step was to review past climate impact assessment research in the Great Lake Basin and to decide where to go next. The document *Climate Sensitivity, Variability and Adaptation Issues in the Great Lakes-St. Lawrence Basin: A Reference Document* (Koshida et al. 1993) provided a basic understanding of the resource bases, institutional framework and environmental issues in the GLSLB to develop links between climate variability and change, and activities in the Basin. This review identified key climate sensitivity, variability and adaptation issues within the GLSLB. The issues

Figure 2.13
GLSLB Project Research Framework



identified in the document contributed to workshop discussions identifying climate-sensitive issues, from which the study concepts for the Project were developed. Three consultative workshops were held, two in Canada (in Québec City and Montréal), and one in Ypsilanti, MI. These workshops brought Basin interests together to discuss and begin to understand the issue of climate change, to develop study concepts, and to identify people to undertake the research. Scenario development and adaptation research formed key elements of the Project. Of the scenarios developed, climate and hydrologic scenarios have been more successful than socioeconomic scenarios. One of the most significant contributions of the GLSLB Project is that it introduced the concept of adaptation into climate impacts research in the Basin. The climate impact and adaptation studies were undertaken on four climate-sensitive themes with many studies incorporating a model of issue identification, scenario use, impact assessment and response and adaptation identification. Integration will be a challenge, but various approaches will be used including the Symposium discussions and the Final Report.

Scenario Development

The GLSLB Project employed a number of climate scenarios, and some of their uses, and strengths and weaknesses will be presented. Most common were scenarios developed from general circulation model

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(GCM) 2xCO_2 runs. Although GCMs provide the best atmospheric science available, they still have shortcomings. The climatological information is at a large spatial scale often in monthly values. Scenarios of changes in variability and extreme events cannot be developed. Impacts researchers must use out-of-date scenarios because of the time lag in obtaining new GCM results. For example, the impacts of sulphur aerosols on reducing regional temperature increases have not yet been incorporated into an impact assessment of the GLSLB. The scenario development technique for annual temperature using the CCC GCMII and current climate information is illustrated in Figure 2.14. In the southern portion of the Great Lakes Basin, the current average annual temperature is 8-10^{o}C. What would it mean if the average annual temperature were to rise to 12-16^{o}C? One might pose similar for precipitation and other climate elements. Four climate transposition scenarios were developed for the Project using the annual temperature increases projected by GCM scenarios and precipitation

Figure 2.14: Climate Scenarios: Temperature

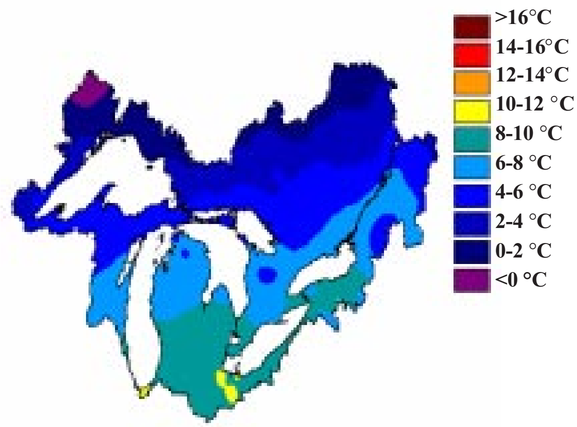


Figure 2.14a 1951-88 annul average GLSLB temperature (basecase)

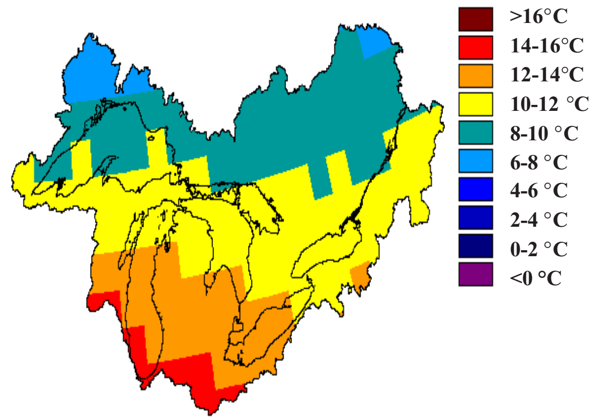


Figure 2.14c CCCGCM 2xCO_2 annual average GLSLB temperature (interpolated onto a 1x1 degree grid)

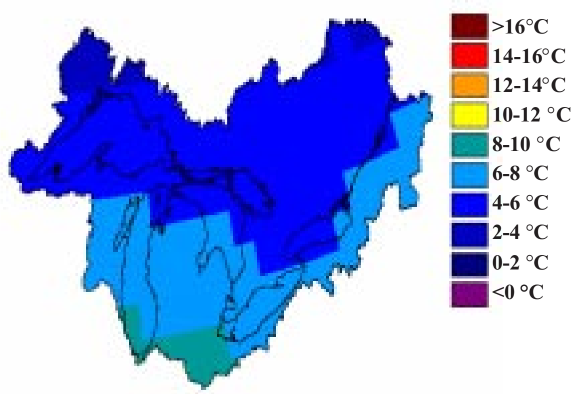


Figure 2.14b CCCGCM 1xCO_2 annual average GLSLB temperature (interpolated onto a 1x1 degree grid)

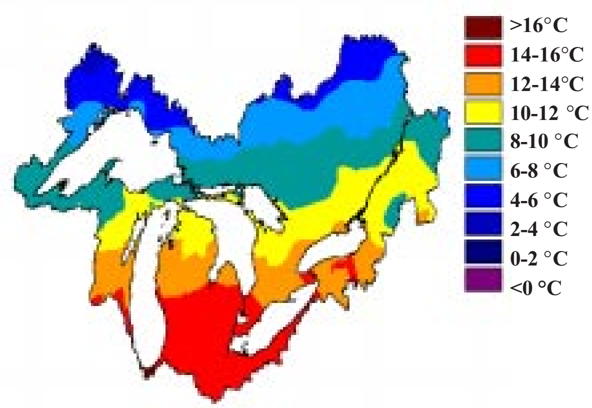


Figure 2.14d Annual average GLSLB temperature climate change scanio (2xCO_2 - 1xCO_2 + 1951-88 basecase)

characteristics (wet or dry) as a guide to select the regions. For example, the climate from a region 6°S and 10°W of the Great Lakes Basin reflecting a warm, dry region was imposed on the Great Lakes to assess effects on hydrology. These scenarios introduce changes in the mean and variability in climatic elements spatially and temporally, and to provide shorter time steps for analysis. However, transposing climates from another region to the study region lends difficulties, such as inappropriate topographic effects.

Historical analogues have been used such as "the 1988 Drought or Heat Wave" and "the 1960s Low Water Levels." G. Koshida and J. Brotton (see Appendix B.), and L. Rissling (1992), respectively, assessed the impact of the 1960s low water levels and the 1980s water level changes. These analogues demonstrate climate vulnerability, serve to document the impacts, and illustrate the adaptations that were undertaken to respond to particular events. They reveal both individual and societal responses. While future climate change may likely be greater and more severe than the historical analogues that were examined by researchers, historical analogues provide a valuable tool to illustrate how extreme events were dealt with in the past. Historical analogues help make issues related to climate change real to policy-makers and decision-makers.

Climate change scenarios must be communicated as possible futures, not as predictions. They provide a "practice climate": "What if?" such a scenario were realized, how would, or should, we respond? What are the personal, political, environmental, social and economic ramifications of such a scenario?

At present, we are not very effective at addressing the socioeconomic scenarios. At the 1988 US-Canada Great Lakes Symposium, Impacts of Climate Change on the Great Lakes Basin, Peter Timmerman used the phrase, "Everything else remains equal" to highlight that in most impact assessments, climate change of the future is imposed on society, technology, population, and socioeconomic conditions of today. However, these will not remain static. Some researchers have sought to address this problem. In the Grand River Study, Southam et al. (1997) projected the effect of population growth to 2021 on water demand, then determined the effects on meeting basin water supply and wastewater treatment targets. Scenarios of climate change reductions in water supply were combined with the projected basin population and water demand. These scenarios illustrate that increases in population and associated water demand will exceed, at some point in the future, the reliable sources of water in the Grand River Basin; climate change scenarios shorten the period of reliable water supply.

Climate Change and Variability Impacts

In the next few paragraphs, findings under each of the four theme areas of the GLSLB Project will be reviewed.

Human Health

In the Great Lakes Basin, climate impact assessments on human health has received the least attention. Under the GLSLB Project, we completed a study examining whether the future mean daily temperature conditions, projected under a CCC GCM II scenario, may be suitable for the development and transmission of *vivax* and *falciparum* malaria in the Toronto region (Duncan 1996). This study considered the physical potential (i.e., temperature conditions) alone and not social, economic, and behavioural factors that also contribute to the incidence of malaria. An analysis of the relationship between weather and heat-related morbidity was undertaken for Toronto (Tavares 1996). At a maximum temperature threshold of 28^{o}C, morbidity cases for the elderly increased (people greater than and equal to 65 years old), while morbidity cases for younger people (under 65 years) increased at a temperature threshold of 31°C. A 2xCO_2 scenario projects more high-temperature days in the summer. The changing age structure in the GLSLB renders that an important planning consideration; the aging baby-boom generation is increasing the most vulnerable population.

Ecosystem Health

There are forty-three areas of concern (AOCs) in the Great Lakes-St. Lawrence Basin for which remedial action plans (RAPs) are being developed and implemented. None of these RAPs have considered climate variability and climate change. One study of the Bay of Quinte watershed indicates there may be changes in phosphorus loading to the Bay and that some sub-watersheds may not be able to achieve their RAP phosphorus loading targets. The higher water temperatures and lower water levels projected with climate change will impact the remedial efforts around the Great Lakes in many ways.

Wetlands are recognized as valued ecosystems that must be preserved. However, they are extremely vulnerable to changes in hydrology. What are the risks to inland wetlands and to shoreline wetlands from climate change? Shoreline wetlands that are open, without barrier beaches, may be able to migrate lakeward to respond to lower lake levels. New wetlands may be created, depending on slope, sediments, and seed banks available for recolonization. However, inland and enclosed wetlands are vulnerable; they may dry and become land.

B. Fooks (1996) reviewed government and private sector management policies and plans for natural areas in the Halton/Hamilton sub-watershed region of the Great Lakes Basin. None of the policies and plans explicitly considers climate change. The promotion of buffers, control of adjacent land uses, development or maintenance of corridors and linkages, monitoring and management for biodiversity would reduce vulnerability to climate change, yet Natural Area Management Plans in southern Ontario do not strongly incorporate these initiatives.

Land Use and Management

B. Singh et al.'s (1997) research indicated that climate change impact findings depend on the scenarios used. For example, if climate change alone is considered in agricultural yield models, crop yields increase and decrease, depending on the crop considered. The crop is vulnerable based on the acceleration of the maturation date and moisture stress. However, if CO_2 fertilization is included, yields increase, at least in the Québec region. One of the major conclusions from this study is that aside from impacts and yield changes, one must also consider the farmer's behaviour, his/her decision-making, management and adaptation to those particular changes, factors not often considered sufficiently in this kind of research. Focus groups with farmers provided information on how climate change and pace of change are perceived. Farmers can adapt to slow, gradual change over a long time; abrupt changes are more difficult to respond to and lead to increased vulnerability. B. Smit et al.'s (1997) research showed that farmers respond to the climate or growing conditions of the previous year for corn hybrid selection. The year following a particularly dry, warm or wet year led to a change in behaviour. After a warm year, farmers seemed more willing to take risks such as choosing a longer maturing crop to enhance yield and after a cool year their adaptive behaviour was much more conservative.

Water Use and Management

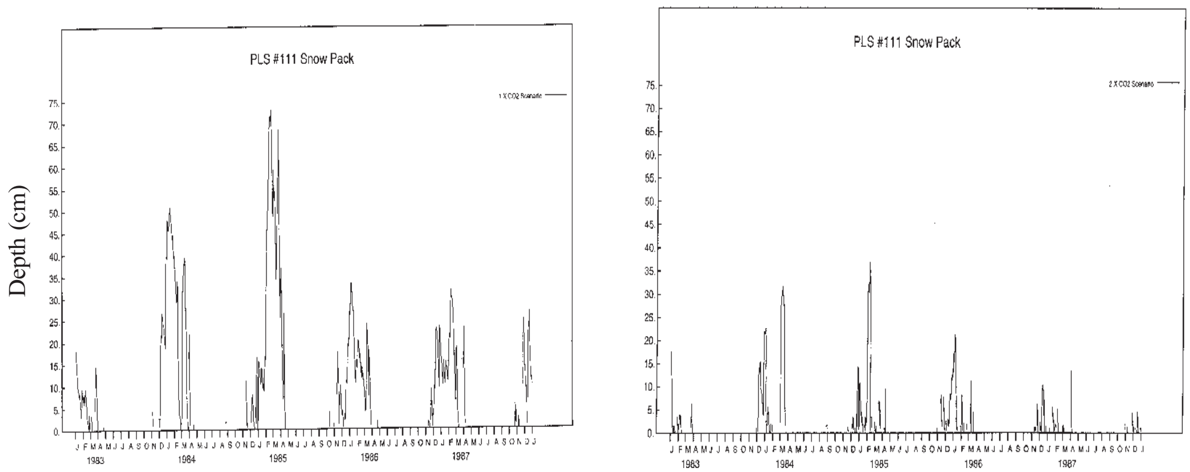
Water use and management in the GLSLB has been subject to the most research; results indicate that the GLSLB region may move from managing for an overabundance of water to managing for scarcity of water due to climate change.

Under 2xCO_2 scenarios, lake levels decline. "What if?" water levels in Lake Michigan-Huron were to drop more than 1m? "What if?" levels dropped 0.8 to 1.9m on Lake Erie and 0.2 to 0.5m on Lake Superior? Lee et al. (1996) used an estimated 1.6m drop in the mean level of Lake St. Clair from the CCC GCMII scenario and Geographic Information System (GIS) modeling to determine the new shoreline configuration. The shore moves lakeward 200m to 6km. "What if?" wetlands, cottagers, boaters, municipal sewage outlets and water intakes will be affected?

The *Lake Ontario Regulation Plan* cannot meet minimum downstream flow requirements under climate change scenarios; consequently, the Lake Ontario Board of Control is considering re-evaluation of the regulation plan. Regulation of the lake must balance upstream interests in Lake Ontario (e.g., cottagers, boaters, hydrogeneration) with downstream interests in the St. Lawrence River (e.g., Port of Montréal, navigation). Lower water levels may require harbours and shipping channels to be dredged. Many sediments contain toxic chemicals; how will dredge spoils be disposed? The impact assessment of the Bay of Quinte demonstrates the change in the duration and amount of snow cover from current conditions to a 2xCO_2 scenario (Figure 2.15 a and b). In the 2xCO_2 scenario there is a significant decrease in the snow cover depth. It becomes more intermittent and almost non-existent in some years. More precipitation falls as rain in the winter because of winter temperature increases; rain falls on snow, resulting in conditions for winter flooding, but causing less snow cover and a reduction in the spring freshet.

S. Changnon (1994) used the Lake Michigan diversion at Chicago as an analogue for climate change impacts and potential responses. His research suggested there will be enhanced controversy over existing diversions, and attempts at new intra- and inter-basin diversions under climate change

Figure 2.15a and b:
Snow Cover for the Current Climate (a) and 2xCO_2 Climate Scenario (b) for the Northwestern Portion of the Bay of Quinte Watershed (Walker, 1996)



a) b)

conditions. During the 1988 drought, barge traffic was affected on the Mississippi River. This led to a request for more diversion of water through the Chicago sanitary and ship canal to augment flow in the Mississippi River. Under *The Great Lakes Charter*, all the State governors and the two Provincial premiers have agreed not to allow diversions of water out of the Great Lakes Basin. However, climate change will challenge institutions and laws dealing with water.

R. Kreutzwiser (1996) identified vulnerable areas in southwestern Ontario for potential conflicts in rural water use, and interviewed people in the region to identify their concerns and to identify desirable, effective adaptations. His work indicated that there will be more conflict and competition between regions over water, and that rural water users are particularly vulnerable, especially where groundwater is the source of their water supply.

C. Southam et al.'s work (1997) on the Grand River Basin indicates that uncertain flows and poor water quality in the Grand River under climate change scenarios will make the inland water supply system more vulnerable and less reliable for regional drinking water supply and the assimilation of waste.

The climate impact assessment integration framework developed for the GLSLB Project is outlined in Figure 2.16. It identifies the cross-cutting research components that should be included in the climate impact assessment studies: climate and physical systems, socioeconomic impacts, adaptation, communication and education and assesses how well those components were integrated into the component studies.

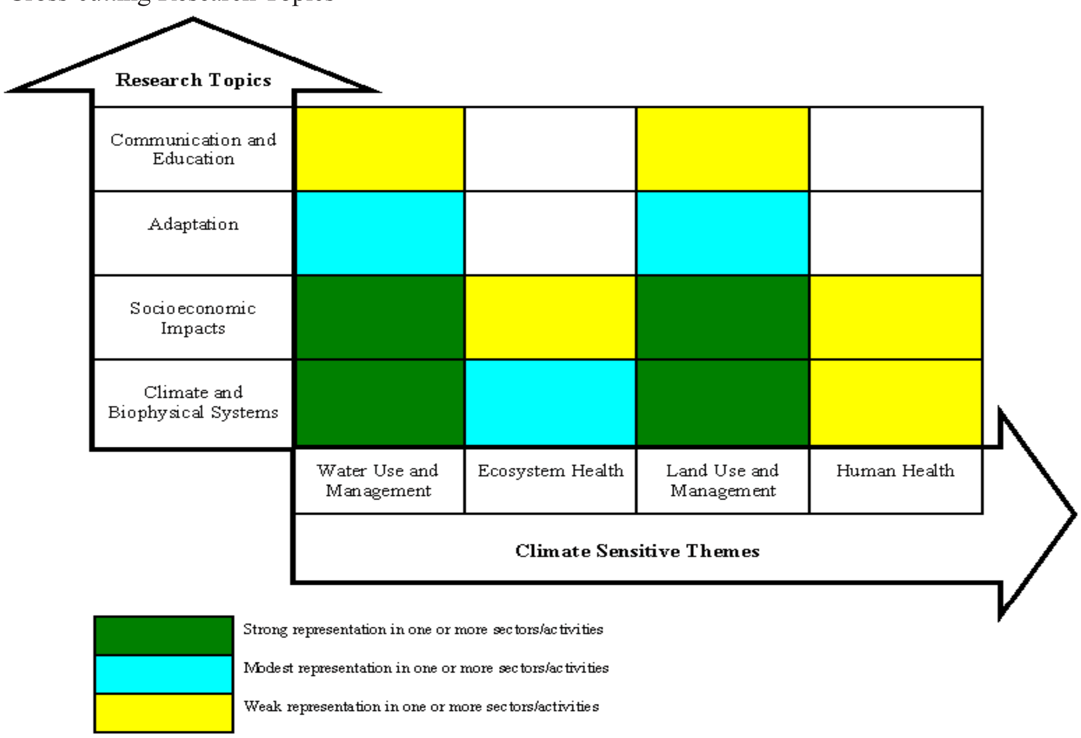
Most advanced are the themes of water use and management, and land use and management, for addressing climate and physical systems, socioeconomic impacts, adaptation, and communicating and educating others. The land use and management studies focused on agriculture and forestry, yet the GLSLB has a large urban component. Research on the effects of climate variability and change on urban areas is required. Ecosystem health has received some attention but requires more research on ecosystem processes and remediation efforts. Research on human health issues within the GLSLB is a significant missing link.

From these climate impacts, one might ask, "So what?" What are the potential adaptation responses?

Adaptation

To paraphrase Donahue (1994), the choices to respond to climate change are: a) "do nothing," b) "assume the worst case scenario," and c) "implement 'no regrets' adaptation strategies." The "do nothing" response means waiting for scientific certainty on estimates of the magnitude and direction of climate change. Then strategies can be designed with confidence and political will for implementation will be present. This may mean reacting to emergency conditions. There is delay in being adaptive. When assuming a worst-case scenario, the policy response can be immediate, aggressive, and affect socioeconomic conditions and behaviour. Aggressive measures are risky

Figure 2.16
Cross-cutting Research Topics

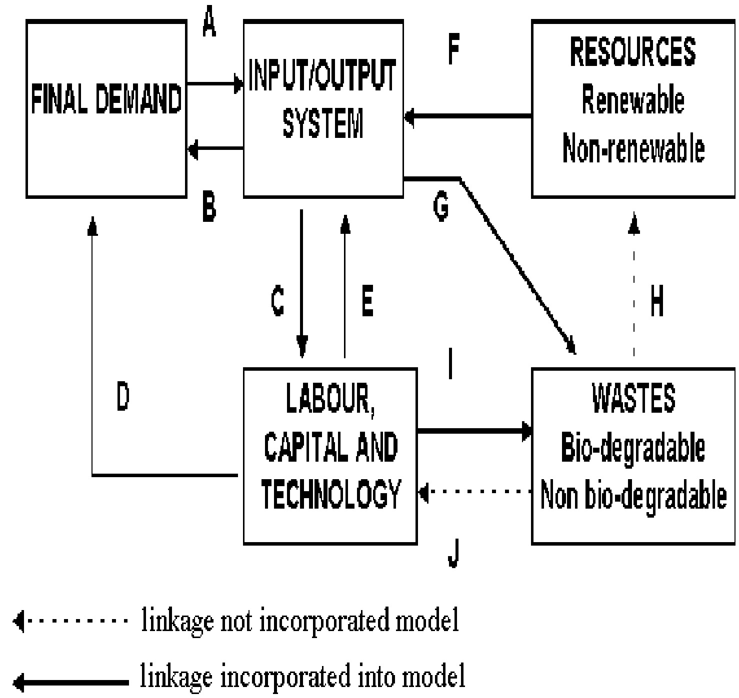


because of the uncertainty in climate change science, and in the effectiveness of actions. As well, initiatives may lack political support.

An alternative is "no regrets" adaptation strategies, actions that make sense now, irrespective of the nature of climate change, and which help to correct other known environmental problems (e.g., water conservation, no-till agriculture). These actions set the foundation for thinking proactively about climate variability and change, and for more aggressive measures if needed. This is an anticipatory, preventative mode.

I. Burton's work on adaptation has led to a typology of adaptations: sharing the loss, bearing the loss, modifying events, preventing effects, research and education, and avoiding the impacts. What adaptations resulted from the GLSLB Project? Studies examining land use and management and water use and management themes advanced and addressed adaptation. In the land use and management theme, two points of view emerged about agricultural adaptation. Farmers are adaptable and can change their crops and techniques, given the impetus to change, but also farmers are maladaptive to climate and thereby incur economic losses. The latter is often because government subsidies help absorb climate-related risks, and discourage adaptation. In water use and management, adaptation was addressed in the Grand River Basin and rural

Figure 2.17
The Environment-Economy Framework for the LINK Model



A. The demand for products determines what the economy produces. The input/output system identifies where the production will take place and what technologies will be used.
B. The economy generates income and taxes which, in turn, supports the demand for products and services.
C. As a result of economic activity, additions are made to the capital stock, such as buildings, roads, machinery and information production.
D. Requirements for new capital goods add to the demand for products from the economy.
E. Capital (including labour as 'human capital') provides services to the economy that are essential for production.
F. The economy requires resources from the environment which are obtained by the industries such as logging and mining, or through direct extraction in the case of water withdrawals.
G. Economic activity generates wastes which, in this context, includes all types of unwanted by-products coming from industry or individual consumers.
H. Wastes disposed into the environment can affect the capacity of the environment to provide some types of resources e.g. the effects of acid deposition on forestry and agriculture.
I. Changes to the economy's capital stock generates wastes (and causes environmental

water use studies (Southam et al. 1997 and Kreutzwiser 1996). Adaptations to streamflow changes in the river were assessed in the context of the Grand River *Vision*, a long-range, watershed planning document. With modest changes in river flow, the goals were projected to be achievable but complicated. Moderate changes in flow would make the watershed goals difficult to achieve and would lead to conflicts among users. When the flow declines became severe, there would likely need to be a "new operating environment" on the river and the goals of the planning document would no longer apply.

When interviewing rural residents in southwestern Ontario on adaptation to rural water supply shortages, the approach of supply management (drill new wells) was preferred over demand management (regulating water withdrawals). Residents also favoured restricting new rural non-farm development, suggesting potential conflicts between rural and urban/suburban residents. Among the methods used to gather ideas were questionnaires, focus groups, and historical analogue analyses.

Integration

Integration is a difficult task. What does integration mean? It means combining parts into a whole, or making them more unified or harmonious. J. Bruce asked those of us at the 1993 Symposium, "Is full integration possible or desirable?" We would answer no, but would suggest that "integration must be purposeful and selective." There should be a distinction made between hard and soft integration. In the GLSLB Project, we have focused more on "soft" integration, where biophysical, socioeconomic and adaptation knowledge are linked by multidisciplinary studies. These are "end-to-end" studies. Quantitative and qualitative information from the climate impact assessments provides input to sustainable development in the Basin, particularly as it affects the policy-making and decision-making process. In the GLSLB Project, we have used a number of integration tools: the binational framework, climate scenarios, an economic tool the LINK model, and GIS. The concept of adaptation has been useful to integrate research results. We have also directed research toward policy targets, such as the *Great Lakes Water Quality Agreement* (e.g., RAPs).

"Hard" integration was undertaken in the Project, but there have been some problems. Figure 2.17 illustrates the components of LINK, an input-output model, used to integrate the results from previous climate impacts on agriculture, tourism, and shipping, as well as new assessments for forestry and energy demand, to assess climate change impacts on the economy of Ontario. Impacts were reflected in the model by changes to current output levels by sector and by county. Among the limitations of this kind of a study is that it traces economic activity, but not wealth or well-being. The impact assessment was undertaken on sectors representing only

10% of the economy of Ontario, in terms of employment. Full integration would not be achievable using this particular model since we could not undertake enough climate impact assessment studies for comprehensive integration. As well, the positive and negative impacts identified in the climate impact assessment studies were obscured by a presentation of the net impact on the Ontario economy. This failed to capture the trade-offs between regions or sectors, and the policy implications.

Communication

Communication is a significant challenge for the climate change issue. How do you communicate an issue that has no real sense of urgency; where there are many uncertainties in the science; which is very complex; and for which there are no easy solutions? Why should you communicate? The goal of communication is to raise awareness, to give people an understanding of the issue and impacts, and to help motivate them to action or change. Communication also helps build support for the climate change issue. Development of adaptation strategies requires effective communication. Including stakeholders in designing and undertaking research for mutual learning should be important components of future climate impact assessments. Communication is often a significant missing link in efforts.

Lessons Learned

From the review of the GLSLB Project, a number of key lessons might be highlighted. We need to:

- address policy and decision-making issues as well as science issues;
- build a multi-disciplinary perspective with commitment to information exchange and appreciation of other disciplines;
- use a range of climate scenarios and link scenarios and impacts to historical extreme events for “grounding in reality”;
- undertake careful, purposeful integration of results;
- identify “no regrets” adaptation strategies;
- communicate impact assessment results and adaptation strategies, and
- include stakeholders in the design and undertaking of research.

Questions/Comments

An unidentified questioner asked for clarification on where data for heat wave-associated mortality came from, observing that critical temperatures differ depending on location.

Another questioner asked whether there might be a challenge in communicating information about climate change to aboriginal peoples, or other unique populations, and effecting adaptation which benefits all populations. L. Mortsch concurred that a link missing in the GLSLB Project is a lack of aboriginal community studies or participants.